Proposition de Thèse au CEA-Saclay/IRFU

Spin-parity of the new boson with the CMS detector

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On July 4, 2012, the ATLAS and CMS experiments at the LHC announced the discovery of a new particle (H) in the context of the search for the Standard Model (SM) Higgs boson [1, 2]. The production and decays of the H particle were found to be consistent with expectations for a SM Higgs boson of mass close to 125 GeV. Most of the sensitivity in the discovery came from two decay channels, $H \to \gamma\gamma$ and $H \to ZZ^* \to 4\ell$.

The present PhD proposal aims at determining two important quantum numbers of the H particle: its spin and its parity. Measuring a spin different from zero would immediately demonstrate that this new particle is not responsible for the electroweak-symmetry breaking since the Higgs boson from the SM can only be a scalar particle.

Because of its decay in two photons, the H particle must be a boson (integer spin) but cannot be a vector boson (spin 1) [3]. Therefore possible spin-parity states for the H boson are $0^{\pm}$ and $2^{\pm}$. Spin and parity govern the configuration of angles between decay products of the H boson and incoming partons, therefore we will study angular distributions in the four body decay $H \to ZZ^* \to 4\ell$, and primarily in the $H \to \gamma\gamma$ decay [4, 5, 6]. Detailed studies of the $H \to 4\ell$ channel, performed in the CMS experiment, showed that distinguishing spin0-spin2 is not expected to be conclusive with the full 2011-2012 dataset, while the parity determination is much easier [8]. A preliminary study carried out by the IRFU/SPP group demonstrated that the $H \to \gamma\gamma$ channel can significantly increase the sensitivity on the spin determination. This study also showed that in this channel, the discrimination is reduced due to sub-optimal performance of the CMS electromagnetic calorimeter (ECAL), especially in its forward regions [7].

Thus, the PhD program will follow three main axis. First, the IRFU/SPP has dominant role in the ECAL calibration group and the PhD student is expected to participate to this effort in order to improve the ECAL performance, crucial for this measurement. The second axis will be the development of the spin measurement in the $H \to \gamma\gamma$ channel for which only preliminary studies are available. The final axis is more phenomenological and covers the understanding of the different spin 2 models, the different ways to discriminate one model from another, and the interplay with the $H \to 4\ell$ analysis.

Supporting staff

The IRFU/SPP played a major role in the conception, development, construction and commissioning of the ECAL, especially of the laser-based calibration system which is crucial to ensure

optimal performance of the ECAL over time. The group has also developed the η-dependent in-situ calibration currently used by the CMS collaboration. As a consequence, it is one of the central group in the ECAL calibration team (present convener of the ECAL detector performance group). On the physics side, the IRFU/SPP has studied the $\gamma\gamma$ production for several years, from the measurement of the diphoton cross section to the H observation in this channel. It also participates to the SM physics group, with an emphasis on diboson production studies (former convener of the electroweak physics analysis group).

References

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